Laser-Based Diagnostics

Fact Sheet

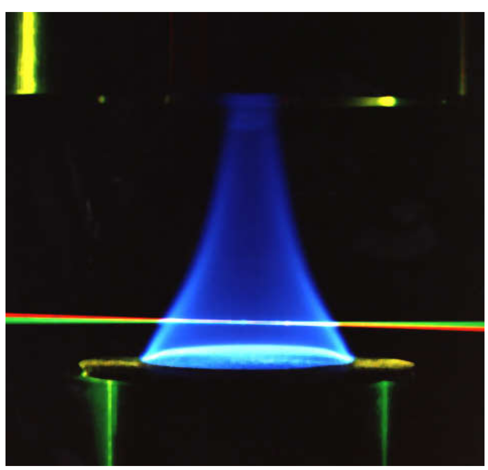
The development and use of laser-based diagnostics is the hallmark of the Combustion Research Facility (CRF). Laser-based technologies are the cornerstone upon which the CRF was founded approximately 20 years ago, and to this day, it maintains an enduring commitment to nurturing staff expertise in this area. In addition, the CRF has one of the most comprehensive collections of state-of-the-art and custom-built lasers used for combustion studies in the world.

Laser-based diagnostics are a necessary tool for the study of combustion. They allow researchers to nonintrusively study and measure fleeting and ever-changing combustion events in a wide variety of environments such as inside engines, burners, and even in huge vats of molten iron in a steelmaking plant.

The CRF's strengths in laser-based diagnostics have extended beyond the realm of combustion studies. This expertise is fundamental to ongoing efforts in remote sensing, specialized lidar for use in studying atmospheric water vapor (a vital ingredient in global climate change), and µChemLab,™ a device able to quickly detect minute concentrations of chemical agents and explosives.

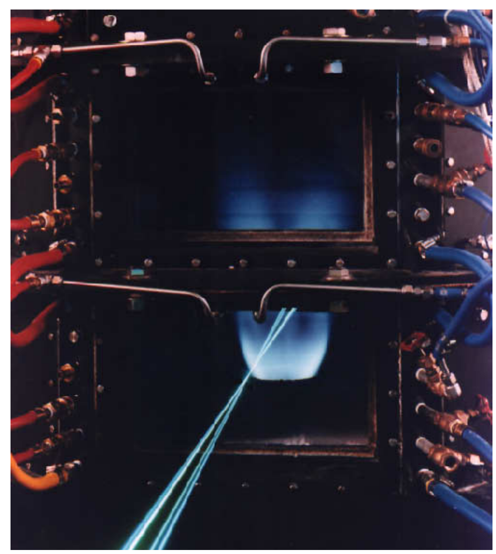
CRF Contributions

Laser-based optical diagnostics have revolutionized combustion research over the past two decades. The CRF has made significant contributions to the advancement of laser diagnostics, which require continued development in the areas of lasers, optics, and sensor systems technologies. In the past decade, the CRF has been a leader within the combustion community in the development of new nonlinear optical diagnostics, advances in fluorescence imaging, and the fundamental research required to make quantitative laser-based Raman and fluorescence measurements.



A crossed-beam Coherent Anti-Stokes Raman Spectroscopy (CARS) experiment is used to measure concentration profiles in a laboratory flame.

The CRF emphasizes the development and application of laser-based techniques for fundamental studies of intra-molecular and intermolecular energy transfer, and of unimolecular and bimolecular chemical reactions. Much of its work focuses on the spectroscopy, energetics, and dynamics of reactive species such as free radicals.



Measurement of two components of the gas velocity in the near field of a 400kW natural gas flame using laser Doppler velocimetry in the Burner Engineering Research Laboratory.

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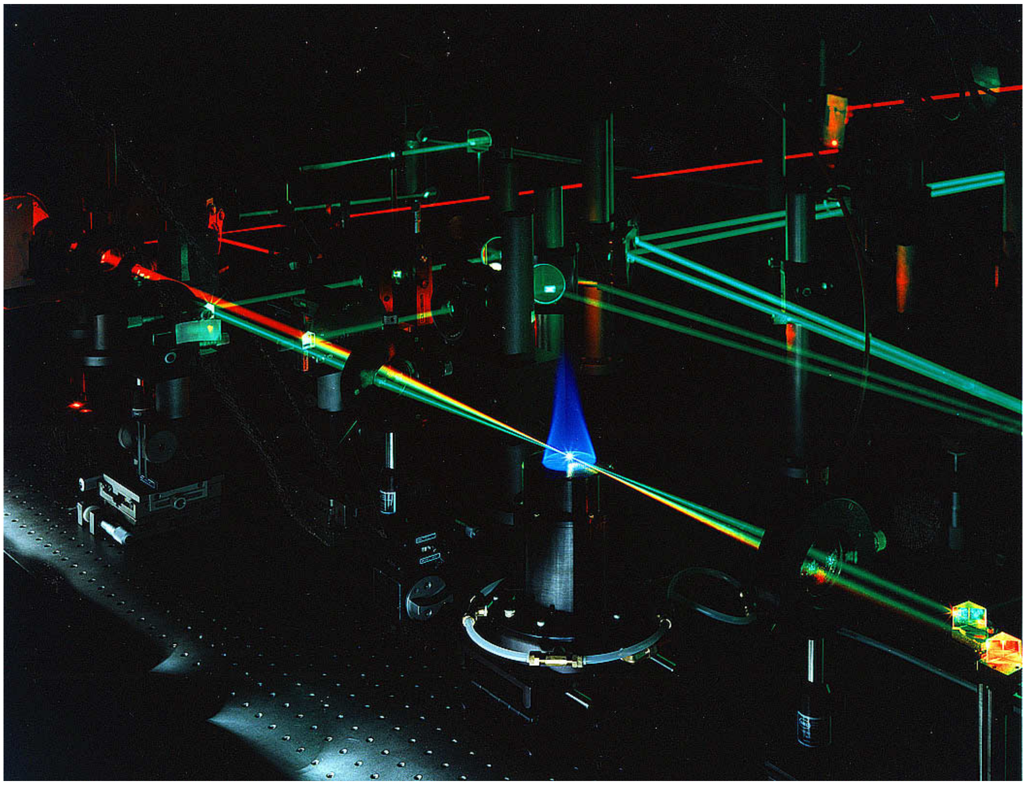
Diagnostics research at the CRF includes three important components:

•The development of innovative approaches and techniques for optical diagnostics

• Research to understand limitations and provide a quantitative interpretation of these methods

•The development and transfer of measurement technology to applications

This work has benefited and furthered the development of new techniques such as coherent anti-Stokes Raman spectroscopy , resonant degenerate four-wave mixing, and thermal grating spectroscopy.



Although this research setup is elaborate, compact and robust CARS instruments have been designed for field measurements in practical devices such as jet engines. The bright spark is the result of laser-induced breakdown that occurred when the flame was extinguished for the double-exposure photograph.

Some of the CRF's unique capabilities and accomplishments include:

- Use of a picosecond laser—new to the CRF—to study collisional processes such as rotational energy transfer and quenching, whereby laser-excited molecules return to the ground state via collisions or other nonradiative processes.

- Use of a combination of laser diagnostics to simultaneously measure temperature and several species concentrations in turbulent flames.

- Use of planar imaging of laser-induced fluorescence and scattering from particles to investigate the interactions of fluid motions and chemical reactions.

- Advancement of the fundamental understanding of nonlinear Raman techniques such as CARS, which stands for coherent anti-Stokes Raman spectroscopy, and is the recognized standard for thermometry of reacting gases.

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